Report from the PAC

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RHIC PAC Meeting Overview

(June 16 – 17, 2016)

STAR presentation of

- Data-taking, analysis progress & key pubs from Runs 14 -15
- Beam Use Request for Runs 17 and 18

PHENIX presentation of

- Data-taking, analysis progress and key pubs through Run 16
- Data release plan

Reports

- Chiral Magnetic Effect Task Force
- Cold QCD Plan for 2017 – 2023

Updates

- sPHENIX
- STAR BES- II and iTPC
- CAD summary of Run 16

Run 16 Summary

Effective operation of detectors and collider:

- Run 16 successful even with 20-day downtime due to RHIC magnet failure

With Run 16 still weeks from completion at time of PAC Mtg

- PHENIX (in its final RHIC run) exceeded its proposed integral luminosity goals for
  - 200 GeV Au+Au
  - 19, 62 and 200 GeV d+Au
  - Integral luminosity projection of ~80% of goal for 39 GeV d+Au

PAC

- deems this a very successful final PHENIX run
- anticipates from both experiments
  - Considerable physics on heavy flavors from Au+Au
  - Being able to address questions on the initial state and anisotropic flow harmonics from the d+Au beam energy scan

STAR Highlights from Runs 14 and 15

- Continued implementation of new detector systems to increase physics scope.
- Muon Telescope Detector (installed permanently before Run 13) has begun to provide new quarkonium data.
- Heavy Flavor Tracker (installed and took data in Runs 14 and 15) is expected to produce significantly new results on heavy flavors.
- The 14.5 GeV Au+Au data represent the end of the first phase of the RHIC Beam Energy Scan. Exciting results presented on the energy dependence of flow and fluctuation observables, and the di-electron mass spectra.
- The Forward Meson Spectrometer (with pre-shower detector) and the Roman Pots expand the forward physics capabilities in STAR.

→*The PAC commends STAR for its continued detector upgrade program and anticipates considerable additional physics from STAR from these runs.*

→ The STAR and PHENIX measurements of a large transverse single-spin asymmetry A_N in p+p and p+A provide new information and a challenge for models on the gluon nuclear wave function.

STAR Beam Use Request 2017

The PAC recommendations for Run 17 *in priority order*

1. 500 GeV p+p with transverse polarization for 400 pb^{-1} with 55% polarization (projected by STAR to encompass 13 weeks of running, with the luminosity throughout the fill optimized to yield a roughly constant ZDC event rate of 330 ± 10 kHz).
   The PAC sees this run as an opportunity to make a landmark measurement and recommends it with the highest priority.

The PAC is aware of the large number of additional spin observables that can be addressed in parallel. The experiment should take full advantage of this opportunity to extend these unique spin measurements to the extent possible.

Collection of this set of data is essential and, if necessary, should supersede any other running during this period.

STAR Beam Use Request 2017 (continued)

The PAC recommendations for Run 17 (continued) *in priority order*

2. 500 GeV p+p for RHICf and RHICf with fixed target for a maximum of 1 week *if solutions for the setup, installation and data-taking are agreeable to STAR and RHIC and in the simplest agreeable configuration.*
3. 62 GeV Au+Au is *viewed as low priority.*

BNL management should consider how best to utilize resources for the 2017 run after the p+p run goals are met.

STAR Beam Use Request 2018

The PAC recommendations for Run 18 *in priority order*

1. 200 GeV ^{96}Ru+^{96}Ru and ^{96}Zr+^{96}Zr, 1.2 billion minimum bias events in each system. *This program represents an opportunity to clarify a central puzzle in the field and thus is of high scientific priority.*

The experimental isobar (Ru+Ru and Zr+Zr) program was proposed initially by STAR last year and has since been bolstered by simulations and the Report of the Chiral Magnetic Effect (CME) Task Force.

This is a compelling program that takes advantage of the flexibility of RHIC and the capabilities of STAR. It should be able to unravel a signal from the CME out of background contributions from flow through measurement of the difference between charged particle correlations across the reaction plane in Ru+Ru and Zr+Zr collisions.

STAR Beam Use Request 2018 (continued)

The PAC recommendations for Run 17 (continued) *in priority order*

2. 2 weeks of 27 GeV Au+Au collisions *if RHIC operates with 13 weeks of cryogenic running in 2018.*

The proposed Λ and anti-Λ global polarization measurement is exploratory and may be related to the vorticity of the QCD fluid formed in non-central heavy ion collisions.

The PAC considers the 27 GeV Au+Au running higher priority than the 62.4 GeV Au+Au running that was proposed for Run 17. The PAC encourages the STAR collaboration to continue to sharpen the physics case quantitatively for the proposed 27 GeV Au+Au running.

STAR BES-II and iTPC Upgrade

- STAR has made significant progress and a compelling BES-II scientific program was presented.
- The iTPC project is scientifically strongly motivated.

The PAC commends STAR for progress made in the last year and is pleased that the iTPC upgrade is an approved ongoing project.

- The construction/installation schedule for the iTPC project appears to be very challenging given the current RHIC run plan.
  The verification and test of installation tooling/procedure during the 2017 shutdown is an important step for the project, though the planned exchange of one outer sector and the possible installation of one new inner sector could be a risk for the scientific program of run 2018.

The PAC recommends STAR monitor the schedule diligently and work with CA-D to possibly allow for more schedule contingency for installation/commissioning prior to the start of Run 19.

Additional STAR Upgrades

- The planned Event-Plane Detector (EPD) will cover a pseudo-rapidity window 2.1 – 5.0 in both beam directions and significantly enhances the reaction plane resolution.

The scientific program of Run 18 can benefit greatly from the improved reaction plane resolution.

- The Endcap Time-Of-Flight (eTOF) upgrade uses the Multi-gap Resistive Plate Chamber (MRPC) modules from the Compressed Baryonic Matter (CBM) experiment at FAIR to configure a STAR endcap TOF detector.

This addition could significantly enhance the PID capability of STAR for its proposed fixed-target running with the RHIC beam.

The funds needed for the EPD and the eTOF project appear modest. *The PAC urges STAR to work with RHIC management and other possible funding sources to secure the support for these upgrade projects and carry out these upgrades as planned.*

Future STAR Measurement Capabilities

The PAC commends STAR for quantitative evaluations of its measurement capabilities for key observables in the BES-II era with the planned iTPC, EPD and eTOF upgrade projects.

These observables included the precise measurement of dv1/dy as a function of collision centrality, critical fluctuations with a large rapidity coverage, precise dilepton spectra, and global polarization measurement. The cases for both the BES-II scientific program and the detector upgrades are made stronger by these simulation results.

STAR Computing and Data Production

Key information presented to the PAC on data release projections

STAR has estimated the following timelines for full production of data from the 2014, 2015 and 2016 data-taking runs at RHIC:

- 2014 Au+Au data to be fully processed by September 2016. 3He+Au data is still in preview production and no estimate was given of when it will be fully produced.
- 2015 p+p data to be processed by August 2016 ; p+Au and p+Al production is queued and estimated to take 5.5 months at 50% farm occupancy
- 2016 Au+Au data production is estimated to take 8 months at 100% farm occupancy; no estimate was given for the production of the d+Au BES data.

The STAR collaboration has expressed concern about continuation of their limited computing resources and disk storage, which the PAC considers to be a very serious issue.

STAR Computing and Data Production

STAR has taken a number of steps aimed to improve the computing bottlenecks within their limited resources:

- During the last year, STAR user jobs have taken advantage of unused CPU cycles in the PHENIX computing farm.
- Effort has been made to involve facilities outside the lab (e.g. Dubna and LBNL-NERSC), which are expected to have up to a 20% impact on the current projection.
- To mitigate problems in storage, a more compact data format is being developed that would reduce the footprint of the data sets by a factor of 5-10.
- A tracking focus group has been investigating possible optimization of the tracking software.

The PAC commends the collaboration for taking these steps and encourages them to take these projects to completion as well as continue to investigate new opportunities. For example, they may evaluate what changes would be needed in the production software, such that production jobs may also use opportunistic CPU cycles in the PHENIX computing farm.

The BNL management is urged to find ways to improve on the current constrained resources in order to enable the timely reconstruction and release of STAR data.

PHENIX Data Production

- PHENIX has fully processed the 3He+Au (Run 14), p+Au and p+Al (Run 15), and has finished online production of the d+Au BES data from Run 16.
- The Au+Au data (Run14) and p+p data (Run 15) will undergo a second pass for improved performance.
- The Au+Au data from Run 16 will take about 6 months to process.

PHENIX stated that all data taken would be processed by the end of 2017. Presently, PHENIX stores all data sets since Run 3 in a compact form, nDST, on disk and available for fast analysis access. With the two large Au+Au data sets from Run 14 and Run 16 adding 2PB, this may not be feasible and further optimization and filtering is being considered.

PAC Recommendations on Computing & Data Production

- *BNL Management should immediately commission a panel of local computing experts to evaluate the STAR needs for computing resources, review the current practices, investigate possible optimization of the use of the local RCF resources, and report within three months.*
- *BNL Management must look into the potential availability and use of additional computing resources within the laboratory, such as the Institutional Cluster within the BNL Computational Science Initiative, or seek additional computing resources, to enable timely reconstruction of STAR data.*
- *The STAR collaboration is urged to adopt their newly developed pico-DST data format before the end of the calendar year, in order to reduce significantly the footprint of the data sets being produced and enable their timely analysis.*

sPHENIX Update

- The PAC commends the sPHENIX collaboration for the progress made last year in the formation of the collaboration organization and leadership team, as well as in the detector prototype and the development of the scientific program of the experiment.
- The recent exercise of deliberation on possible detector descoping options, and the cost reductions associated with these options, requested by the BNL ALD has been informative.
- The tracker options remain a major uncertainty and will be reviewed in September 2016.
- The sPHENIX collaboration identified a reference configuration consisting of three layers of MAPS inner tracker, TPC, EMCal, Inner HCal and Outer HCal detectors.
- The preliminary results from the EMCal and HCal prototypes appear to satisfy the sPHENIX requirements. It is not clear that the tested EMCal prototype will meet the EIC Barrel EMCal requirements.

sPHENIX Update

- If the sPHENIX detector is to be a possible day-1 detector at a future EIC facility, sPHENIX must consider whether the EMCal can be constructed with performance that meets the more stringent EIC detector requirements, while maintaining approximately the same cost. *sPHENIX is encouraged to address this question.*
- The options for descoping the sPHENIX detector from the reference configuration have consequences of varying degrees on the science program. The impact still remains to be evaluated quantitatively.
- *The PAC commends the sPHENIX collaboration on the progress made thus far and urges it to work closely with BNL management on the budget constraints and to seek other possible funding sources in order to reach an optimal detector configuration that will meet the challenges of both construction schedule and scientific performance.*

Cold QCD Plan

- The document lays out potential mid-term perspectives for p+p and p+A collisions at RHIC, including proton polarization.

The PAC commends the authors of the RHIC Cold QCD Plan for the large amount of work they have invested. The overall result is impressive and justifies further studies, beyond that recommended for the polarized p+p run of Run 17.

- Many interesting measurements (besides the sign change of the Sivers function and TMD evolution which are the focus of Run 17) are presented that could justify another spin run before 2023. It is crucial that the data from Runs 15 and 17 be analyzed and published to serve as a basis for projections for future measurements and their impact.
- These analyses, and any resulting new understanding of physics questions for the EIC, could significantly impact optimization of future EIC detectors and interaction regions for physics.

The PAC advises the laboratory to work with the cold QCD community to highlight those cases in which pre-EIC running could significantly inform the EIC instrument design and luminosity needs.

Cold QCD Plan

Part of the physics program of the Cold QCD Plan requires detector upgrades in the forward region. This applies to both sPHENIX and STAR. *The PAC was not in a position to be able to discuss details of costs related to such upgrades.*

In general, the PAC encourages the management and the collaborations to consider a potential (polarized) p+p and/or p+A program before 2023. In addition to the scientific benefits, this would help to keep the Cold QCD community at RHIC engaged, which might be important for the activities at BNL aiming at an EIC. It would also be helpful to further prioritize measurements by considering both the scientific impact as well as budget constraints.

Chiral Magnetic Effect (CME) Task Force

In 2015 the PAC recommended that BNL convene a working group of experimentalists and theorists to critically assess the present state of understanding of the CME and to map out a strategy for how best to use the present suite of measurements to address open questions of interpretation. It should also help to sharpen the case for the isobar collisions that STAR has proposed.

The PAC commends BNL for forming such a Task Force in a timely fashion. And, the PAC highly commends the Task Force itself for meeting the challenge posed last year, in full. Their report provides the requested critical assessment succinctly and incisively. It will provide essential guidance for next year's PAC as it has for us, and we encourage report public via posting for the community on the arXiv.

Although it is not our focus as a PAC, we appreciate the way in which the Report sets out the priorities for theory and modeling. We fully concur with the Task Force that it is important that the community of interested theorists take up the challenges described in this section of the Report.